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ABSTRACT

Designed for use by individuals enrolled in vocational agricultural classes, these student materials deal with setting up and using a tripod level, staking out foundations, differential leveling, and staking out fence lines. Topics covered in the unit are different kinds of tripod levels, the parts of a tripod level, transporting a tripod level, checking and adjusting a level, using a target rod, terminology used when operating a farm level, staking out foundations, differential leveling, and staking out fence lines. The unit includes instructional text as well as five suggested student activities based on the text. (MN)

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STUDENT MATERIALS

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FARM LEVEL - SETTING UP AND USING THE TRIPOD LEVEL, STAKING OUT FOUNDATIONS, DIFFERENTIAL LEVELING, AND STAKING OUT FENCE LINES

1. THE KINDS OF TRIPOD LEVELS

There are several kinds of tripod levels which vary considerably in quality, cost, and accuracy. The most common types of tripod levels are the wye, dumpy, architect, drainage, and farm level.

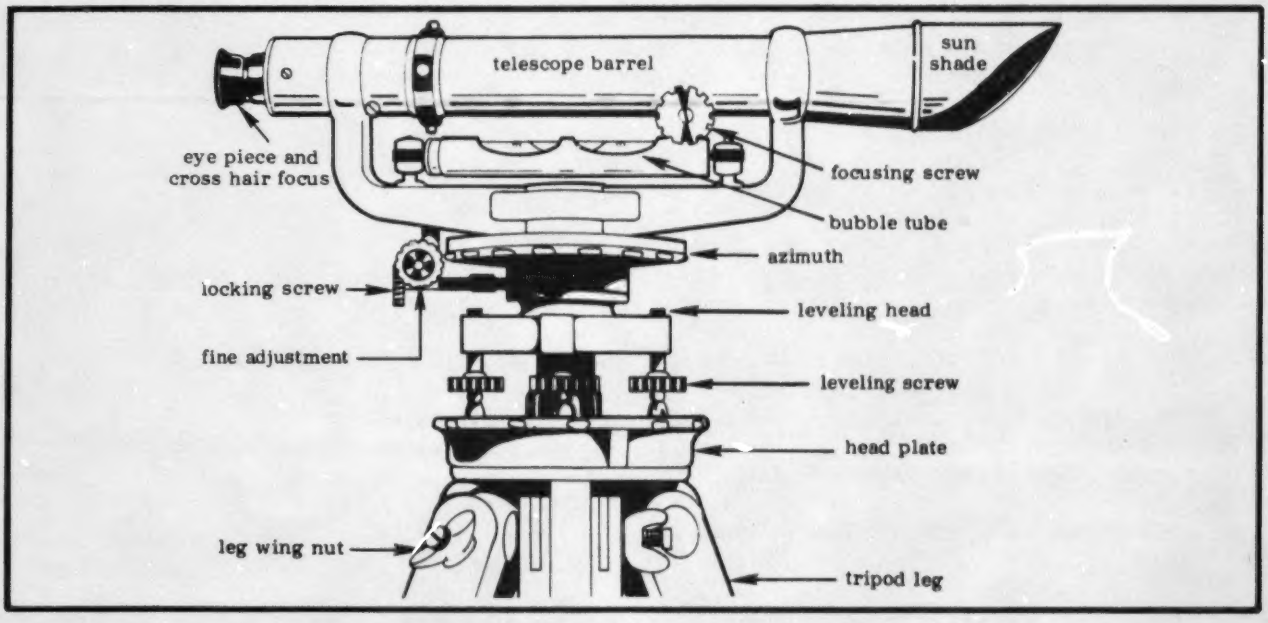
The wye level is the most expensive and gets its name from the method used to attach the telescope to the rest of the level. The telescope, attached by two wyes, may be easily removed and adjusted. This level may have either three or four leveling screws.

The dumpy level has a bubble tube attached to the telescope which is difficult to remove from the rest of the level. It is cheaper and easier to adjust than the wye and may have either three or four leveling screws.

The architect and drainage levels are similar to the dumpy and have plumb bob attachments (an attachment used to mark a point).

The farm level is also similar to the dumpy level. It is adequate for most farm jobs, inexpensive, simple to use, accurate, and with proper care will give excellent service. The two types of farm levels are the turret and the utility. The turret type has three leveling screws, while the utility type has four leveling screws.

2. THE PARTS OF A TRIPOD LEVEL



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3. TRANSPORTING THE TRIPOD LEVEL

A level must be handled and transported properly if it is to be accurate and give service. Suggestions for handling and transporting a level are as follows:

a. The level should be protected from shock and vibration;

b. The level should be kept in its box except when it is being used;

c. The level should be screwed firmly and with care when fastening it to the tripod;

d. The level and tripod should be carried on the shoulder except when walking through brush, then it should be carried under the arm;

e. The moving parts should never be forced;

f. The leveling screws should be snug against the leveling plate;

g. The lens on some levels should be protected from the direct rays of the sun by using a sun shade;

h. The lens should be cleaned with a soft cloth or tissue;

i. The lens should not be removed from the telescope; and

j. The tripod nuts should be loosened before picking the instrument up or setting it down.

4. CHECKING AND ADJUSTING THE LEVEL

The following steps should be used in setting up the level:

a. The tripod legs should be set firmly and at least 3 1/2 feet apart;

b. The wing nuts should be tightened on the tripod head;

c. The level should be securely screwed to the tripod head;

d. One of the tripod legs should be spiked firmly in the ground;

e. The telescope should be turned over the spiked leg and one of the other legs, and the second leg should be spiked and moved in or out until the bubble is visible in the bubble tube;

f. The level tube is turned over the third leg, and it is spiked and moved in or out until the bubble is visible in the bubble tube; and

g. The leg nuts should be tightened on the tripod legs.

Before leveling the instrument, the leveling screws are placed in the mid position in the bosses. This places the center spring under light tension and allows the screws to be raised or lowered as needed. The turret should turn freely.

Leveling the Turret Type Level - The steps in leveling the turret type level are as follows:

a. The telescope is placed over two of the leveling screws, and the bubble is centered by turning the leveling screws equal distances in opposite directions. This may be accomplished by moving the thumbs toward or away from each other.

b. The telescope is set directly over the third screw, and the bubble is centered by turning the third screw.

c. The leveling process is repeated in each of the above steps until the bubble remains centered in the bubble tube.

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Leveling the Utility Type Level - The procedure is as follows:

a. The telescope is placed over two diagonally opposite leveling screws, and the bubble is centered by turning the screws equal distance in opposite directions. The thumbs should be moved toward or away from each other.

b. The telescope is turned over the other two diagonally opposite leveling screws, and the bubble is centered.

c. The leveling process is repeated in each of the above positions until the bubble remains centered in the bubble tube.

The farm level should be checked for accuracy each time before it is used. The parts that should be checked are the bubble tube, telescope, and cross-hairs. The turret type and utility type levels are checked in the same manner.

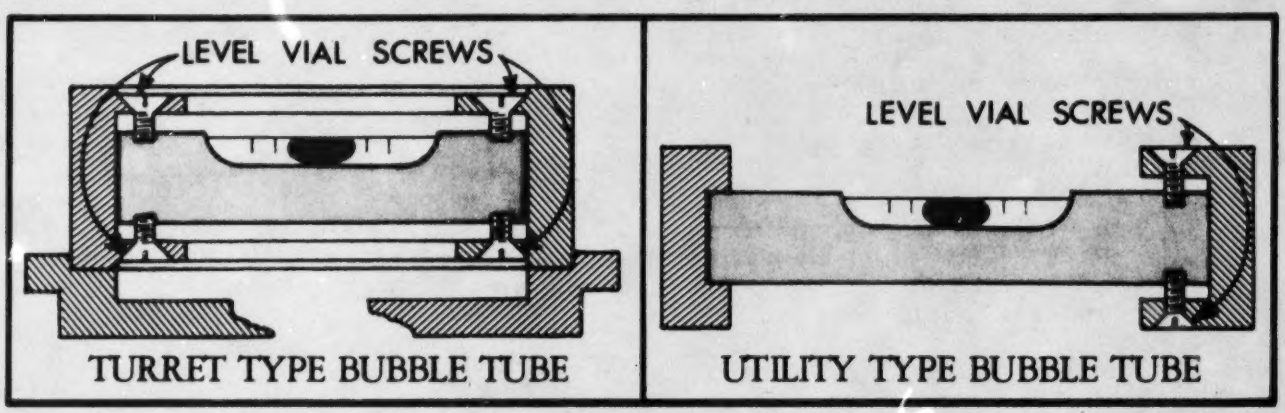
Bubble Tube - The bubble tube is checked as follows:

a. The bubble tube is placed over two of the leveling screws, and the screws are turned in or out until the bubble comes exactly between two corresponding vial lines.

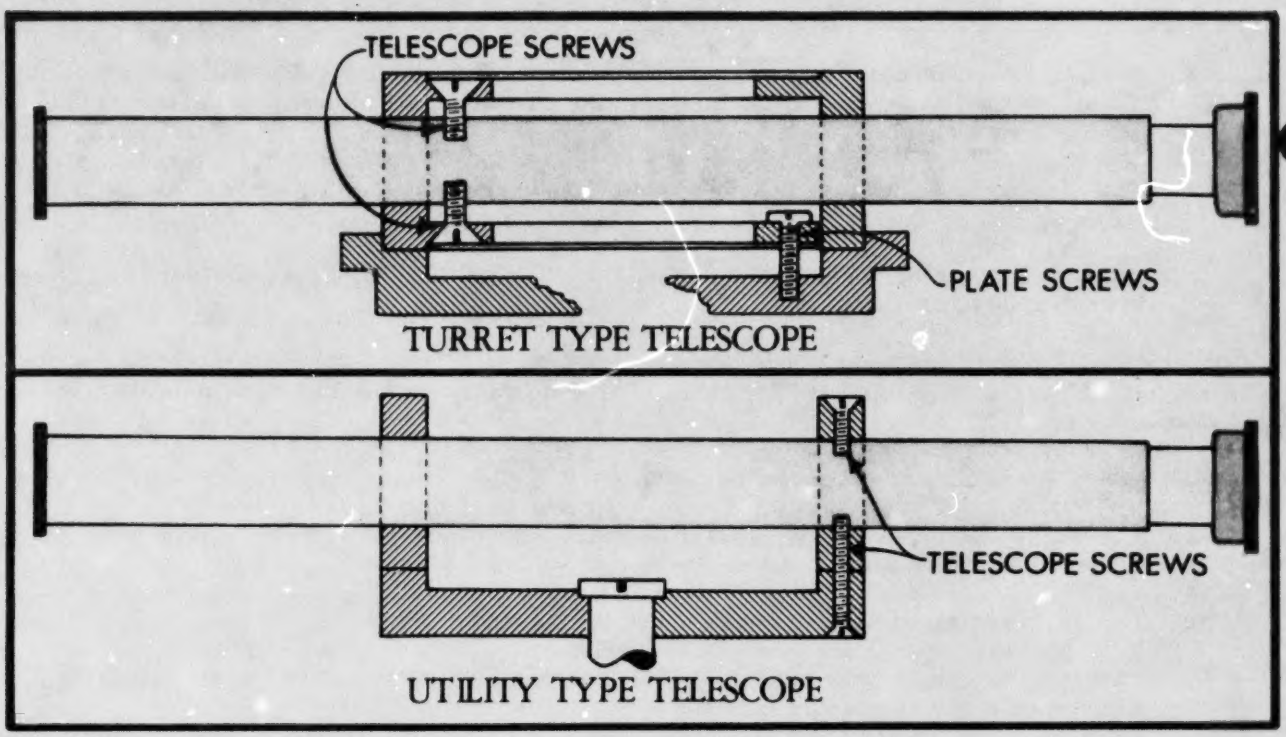
b. Then the turret is swung 180 degrees so that the bubble tube is end for end from the first position. If the bubble does not come exactly to the center between the vial lines as at first, one-half of the amount is corrected by the same two leveling screws. The other half of the difference should be adjusted by the level vial screws shown in the illustration.

The three screws that hold the turret in place should be screwed out to remove the turret and telescope.

The bottom screws on the low end of the tube are loosened and the top screws are tightened. The test and adjustment should be repeated until the bubble stands between the vial lines regardless of the direction the level vial tube is turned. The bubble tube on the utility level is adjusted with two vial screws shown here:



Telescope - There are two tests that should be conducted on the telescope. One is testing the telescope by inverting the turret, and the other is by testing to see if the line of sight is level when the bubble is centered. The first test is made after the instrument is leveled by focusing the telescope on a definite spot 200 to 300 feet in the distance with the turret in the correct position. The turret is then inverted and a sight is taken on the spot. If the center of the horizontal cross-hair remains on the spot, it is properly adjusted. If the telescope needs adjusting, the small screws at the front (where the telescope goes through the turret) should be adjusted to eliminate half of the error. The process should be repeated until the reading remains the same with the turret in the correct position and in the inverted position.



The second test (a test to see if the telescope is in the line of sight of the level when the bubble is centered) is conducted as follows:

a. Stakes A and B are driven in the ground 100 feet apart, or some other convenient distance. In the same line but in the opposite direction, Stake C is driven in the ground. The distance between AC and AB should be equal, and the tops of stakes B and C should be set at the same level.

b. The instrument is set over Stake A and the rod is held on Stake B. The target rod should be adjusted so that the horizontal cross-hair bisects the target.

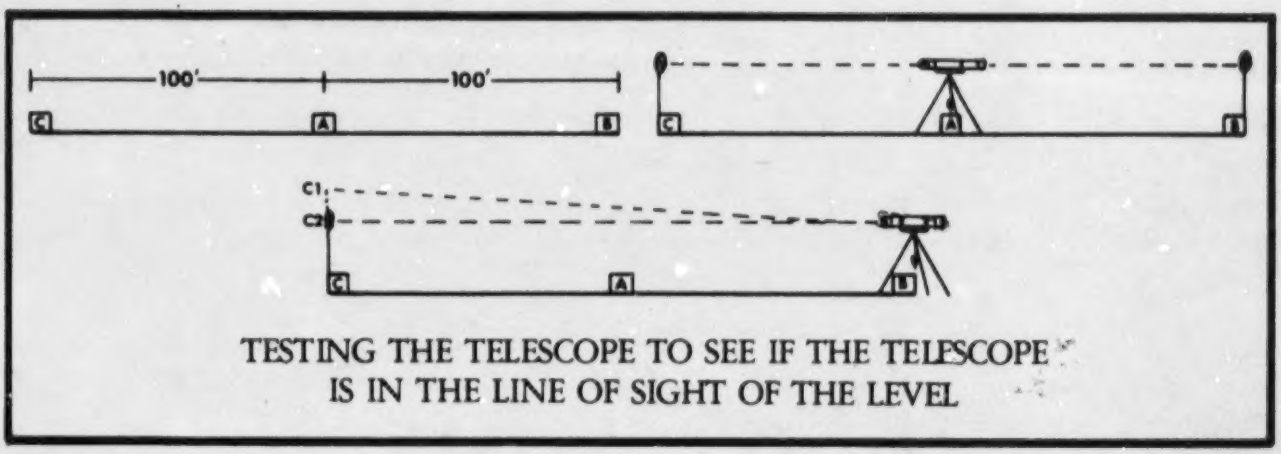
c. The target setting is read and recorded.

d. The target setting is not changed, and the rod is moved to Stake C. Stake C is moved up or down until the cross-hair bisects the target when the rod is held on Stake C and the bubble is in the center of the tube. If it is necessary to raise the stake, it should be pulled up too far and gradually driven into the ground until it is the correct elevation. The accuracy of the test depends on the stakes being at the same level.

e. Then the instrument should be moved to within three or four inches of Stake B and leveled.

f. The rod then is set on top of Stake B, and the target is adjusted until the cross-hairs bisect the target.

g. Then the target rod is left at this setting and carried to Stake C where it is placed on top of Stake C, and a reading is taken. If the cross-hairs bisect the target, the line of sight is level when the bubble is centered. If the cross-hairs do not bisect the target, the telescope should be adjusted by the screws at the front of the level frame. The front end of the telescope is raised by unscrewing the bottom screw and tightening the top screw. The telescope is lowered by moving the screws in the opposite direction.

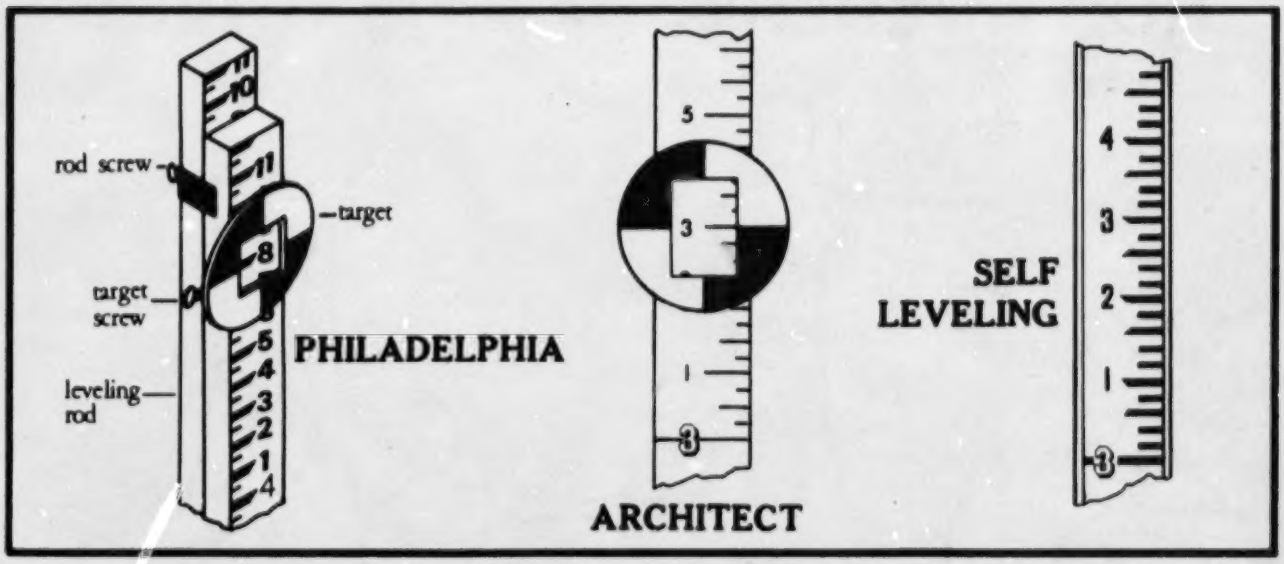


TESTING THE TELESCOPE TO SEE IF THE TELESCOPE IS IN THE LINE OF SIGHT OF THE LEVEL

Testing the Cross-Hair - The cross-hairs are tested after the instrument is leveled and the telescope is adjusted, which is accomplished by moving the slide tube in or out until the object comes in focus. The horizontal cross-hair is focused on a definite point, and the level is rotated back and forth slightly from side to side. If the ends of the cross-hair remain on the point in the same place as the center, the cross-hair is in adjustment. If the cross-hair is out of adjustment, the instrument should be sent to the company to have it adjusted.

5. USING THE TARGET ROD

Three types of target rods are the Philadelphia, architect, and self-reading or leveling rod.



The Philadelphia rod is graduated in feet, tenths, and hundredths; and the architect rod has the same graduations, but is much lighter and shorter. The self-reading rod is graduated in feet, tenths, and hundredths and is used principally for surveying land, running drainage lines, and general soil conservation work.

The Philadelphia and architect target rod have extensions. The target must be set at the same reading on the face of the rod before it is extended to equal the lowest reading on the back of the extended rod. The target should always represent a true reading and should be raised to the top of the unextended rod section before the rod is lengthened. The target rod has very few parts, but a student should become familiar with the parts and their function if he is to use the rod properly.

The rod is used to measure elevation or comparative heights of objects in their relation to the height of the instrument. For example, a rod reading of three feet at one point and five feet at another point is a difference in elevation of two feet at these two points. Grades are established by moving the target a distance over the ground. The grade is raised when the target is lowered, and the grade is lowered when the target is raised.

Instructions to Rodman - To hold the rod, the rodman stands behind the rod and holds it in a vertical position. If the rod is allowed to lean in any direction, the reading will be inaccurate. The rod is usually held by the left hand, and the target is moved by the right hand.

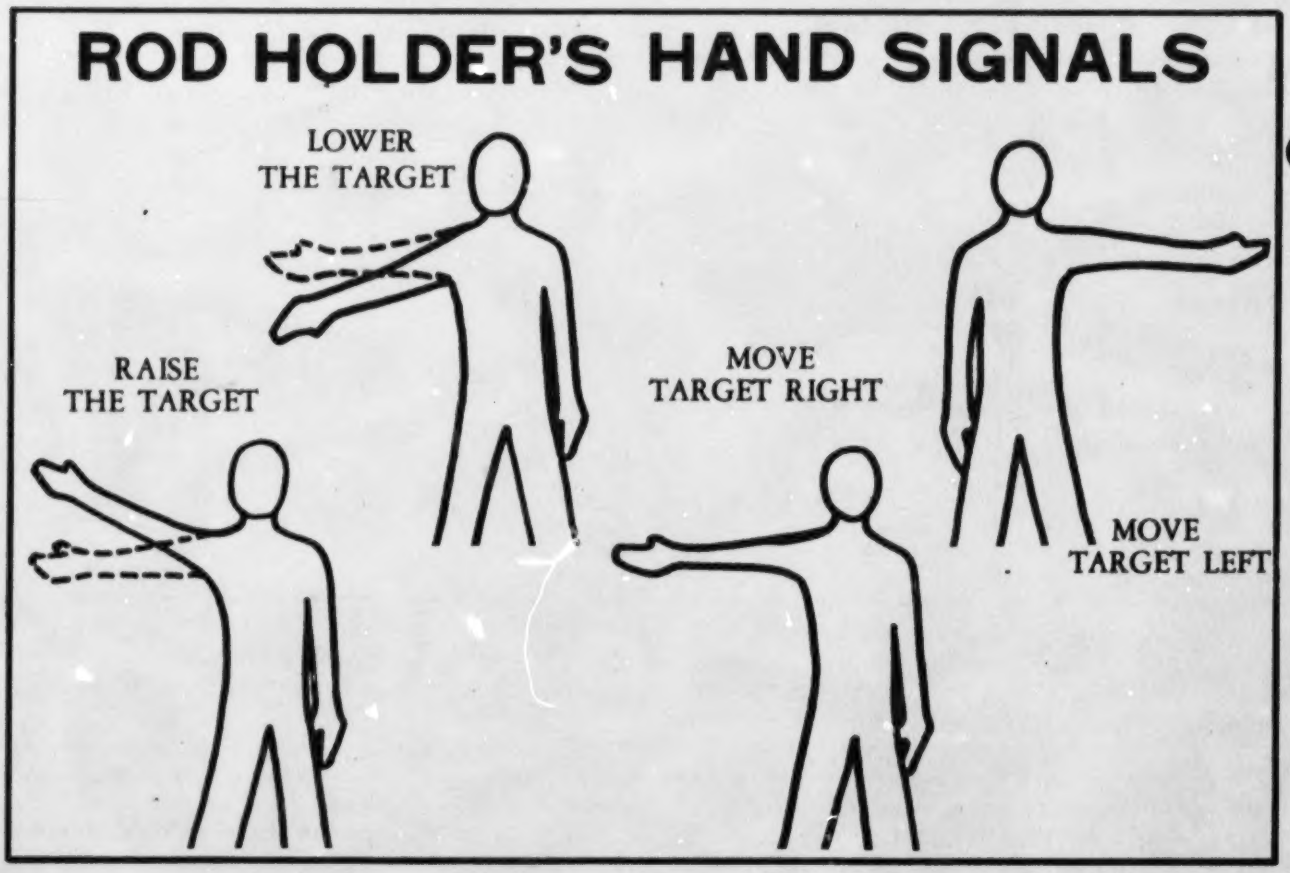
The rodman should place the rod on firm ground before a reading is taken by the person operating the instrument. The rod should not be placed in a depression or on a large clod of dirt to get a reading. In freshly plowed land, the rod should be placed on a foot print that has had a person's weight on it.

When the rodman is several hundred feet from the instrument, it is necessary that hand signals be used. The following illustrations show some hand signals that may be used.

Raise the Target - The palm of the right hand is up, and the arm is raised upward.

Lower the Target - The palm of the right hand is down, and the arm is moved downward.

Move the Rod to the Right or Left - The hand is extended in the direction the rod is to be moved. A long sweeping motion is used to indicate a long distance, while a short quick motion is used to indicate a short distance.



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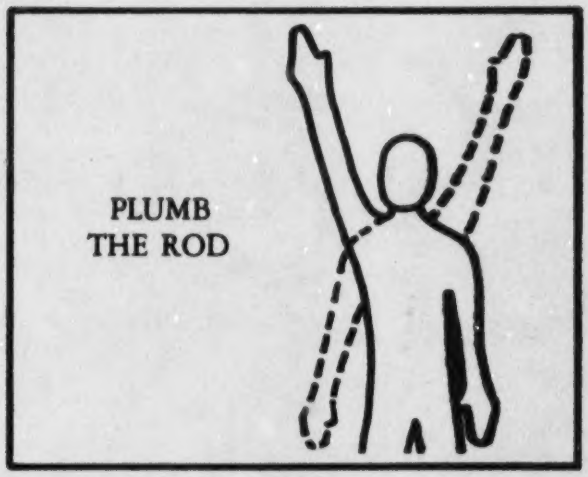
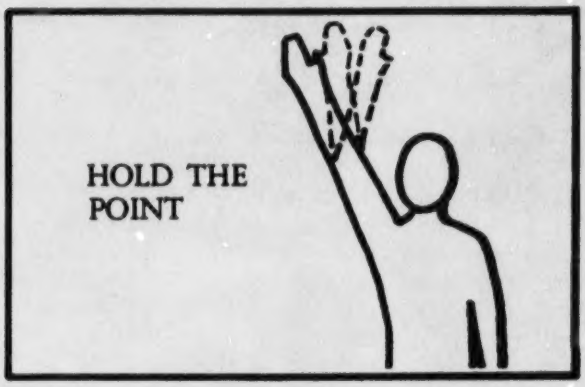
Plumb the Rod (place the rod in a vertical position) - The arm is extended to full length above the head and is moved slowly in the direction required as shown by the vertical cross-hair in the telescope.

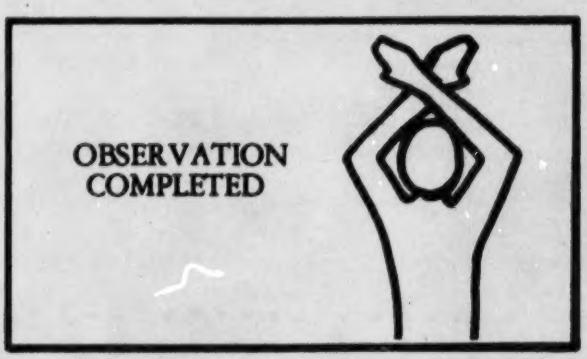


Hold the Point (used to signal that the level is going to be moved) - Extend the right arm the full length above the head and wave in a circle. The rodman must not move until a backsight has been taken after the level has been set up at another point.



Rodman Has Moved the Target - The right arm is extended at a 45-degree angle from the body, and the palm of the hand is placed on the rodman's head. This signal is used by the rodman.

Observation Completed - Both arms are extended above the head and crossed.



6. TERMINOLOGY USED WHEN OPERATING A FARM LEVEL

a. Differential Leveling - the process of determining the differences in elevation between points without regard to alignment.

b. Starting Point - a point of known elevation (bench mark, BM) or an unknown but assumed elevation (temporary bench mark, TBM).

c. Back Sight (BS) - a rod reading on a point of known or assumed elevation.

d. Height of Instrument (HI) - the elevation of the line of sight above a datum or reference surface.

e. Fore Sight (FS) - a rod reading on a point of unknown elevation.

f. Turning Point (TP) - a stable point, first of unknown elevation and then known elevation, used to carry forward a line of levels.

g. Double Rod Leveling - simultaneous differential leveling.

h. Instrument Operator - the person responsible for using the tripod level and keeping field notes.

i. Rodman - the person responsible for positioning the rod.

7. STAKING OUT FOUNDATIONS

Because constant improvements are being made in the production and marketing of agricultural products, most farmers sometime in their careers will find it necessary to remodel and enlarge existing farm buildings, build new buildings, or both. To decrease expenses, farmers will build or supervise this construction; therefore, it will be necessary that they understand how a building foundation is staked.

Farm buildings are laid out in many sizes and shapes, but the same basic procedure is used to lay out the foundations on all buildings. Most buildings are rectangular; however, many have projections and re-entrant parts. There are separate procedures for laying out a rectangular foundation and a foundation with projections. Instructions for laying out a rectangular foundation are as follows:

a. The position of one corner (C) is determined. If the building is to be parallel to a farm road or another building, the farmer will want to measure the same distance back from the road or building in two places (NC and OP).

b. The level is set up and leveled with the point of the plumb bob over point C.

c. The telescope is sighted at P and clamped in this position. CD is measured so that it is the desired length of the building.

d. A stake is set at D in line with the vertical cross-hair of the telescope.

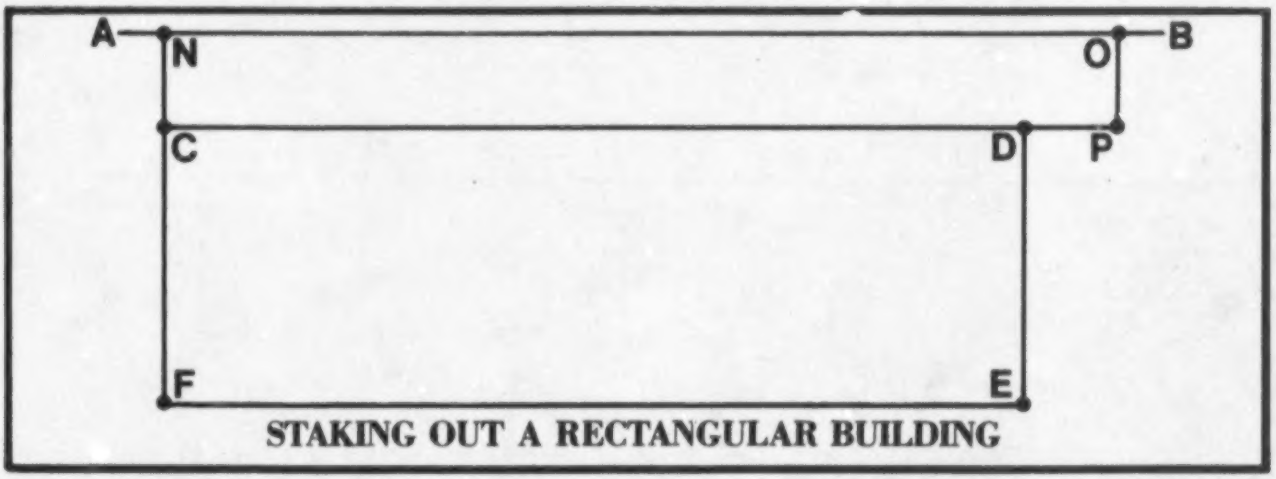
e. The telescope remains in the locked position after sighting at D, and the graduated circle is turned until one of its zeros coincides with the zero of the vernier.

f. The telescope is turned 90 degrees and sighted on point F. The distance from C to F is measured to get the desired width of the building.

g. The instrument is moved to D, and a stake for the E is set in manner as was F.

h. The points and measurements are checked for accuracy. The following procedure may be used:

(1) FE and CD should be measured and be the same.
(2) The instrument is moved to E, and the angles DE and EF are checked to see if they are 90 degrees.
(3) The two diagonals CE and FD should be measured. They should be equal.



STAKING OUT A RECTANGULAR BUILDING

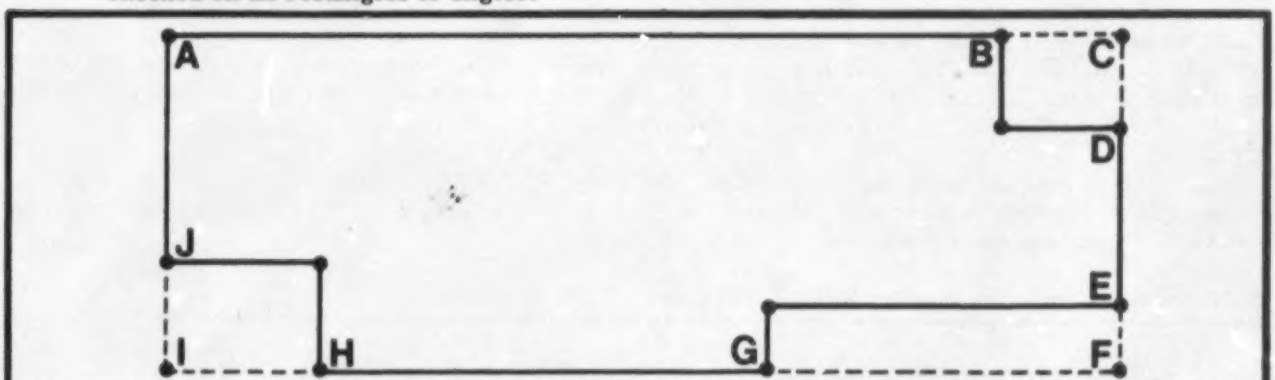
Some buildings will have projections or re-entrant parts which will make them more difficult to lay out. The procedure for laying out this type of foundation is as follows:

a. The main rectangle should be laid out first, and the smaller rectangles laid out afterward in the same manner. If one starts at one corner and continues around the building, errors will accumulate.

b. The rectangle ACIF should be laid out first.

c. The small rectangles are then laid out.

d. The points and measurements, as explained in laying out a rectangular foundation, should be checked on all rectangles or angles.



LAYING OUT A BUILDING WITH PROJECTIONS OR RE-ENTRANT PARTS

The batter boards are set up after the foundation is staked. The procedure to use is as follows:

a. The level is placed in a convenient location.

b. The height of the masonry is determined. The rod is held on the mark which designates the height of the masonry, and the target is set so it is bisected by the horizontal cross-hair of the level. The reading is taken and recorded. This reading will be used on all batter boards.

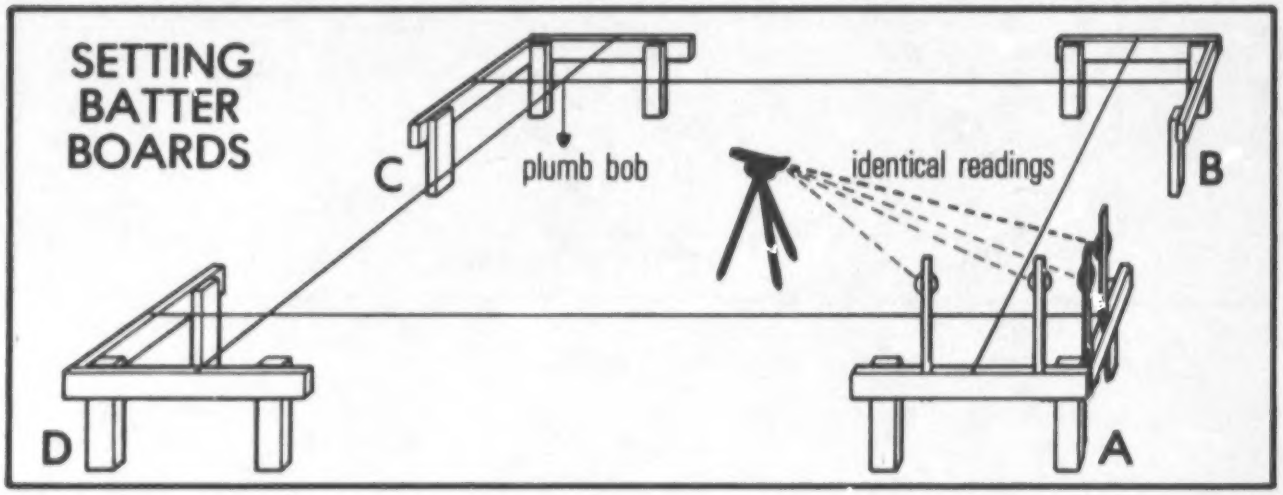
c. The batter boards at corner A are located. The board is raised or lowered until the target is in the cross-hair.

d. The height of the batter boards at the other corners is determined in the same manner.

e. String should be tied to the batter boards so that it will intersect directly over the four corners. The points where the string is attached to the batter boards should be marked. A nail may be driven at this point to hold the string, or a shallow saw cut may be made to hold the string.

f. The string is removed while the foundation is being dug. After the foundation has been dug, the batter boards should be checked to see that they are still level.

g. The line is established by setting the level over stake A, leveling it, and sighting to stake B. A plumb bob may be used at corners to see if the string intersects the point of each stake.



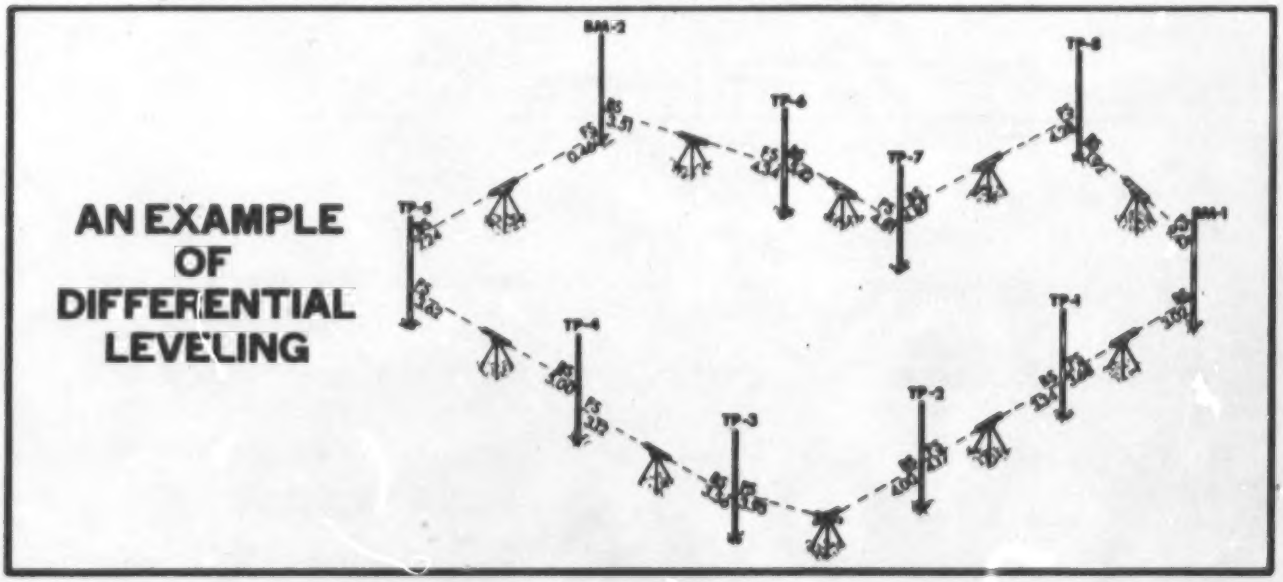
8. DIFFERENTIAL LEVELING

Differential leveling is used by a farmer to determine the differences in elevation at different points on the farm. The establishment of the elevation at different points is useful in running drainage lines and building soil conservation structures. These points are referred to as bench marks, after the elevation at different points has been taken and the elevation becomes permanently established.

A bench mark may be a point on a large boulder, concrete slab, or some other permanent point or spot. A bench mark can be established by driving a length of pipe (4 feet is recommended) into the ground within one-half inch of the surface. The purpose of a bench mark is to have a point with a known elevation which can be used as a reference point to determine the elevation of unknown points.

The elevation of a bench mark may be its height above sea level, if this information is known. It is customary in farm surveys to assume the elevation of the first bench mark to be 100 feet and to determine the elevation of all other points in relation to this bench mark.

The following illustration assumes that the elevation at BM-1 is 100.00 feet.



The following procedure can be used in completing the preceding differential leveling example:

a. To determine the elevation at BM-2, set up the instrument at some convenient distance from BM-1 and in the direction of BM-2. The distance will depend on the accuracy of the instrument and should not exceed 350 feet. If possible, the instrument should be located near the center of two readings, BM-1 and TP-1 for example.

b. A reading is taken and recorded on BM-1. As indicated, this reading is 3.02. This reading is known as the backsight (BS), which is a reading taken on a point of known elevation. BS readings are also known as "plus sights" because they are added to the elevation of the last known point to give the elevation of the line of sight, called the height of instrument (HI). The HI at BM-1 is 103.2 (100.00 + 3.02).

c. The next reading is taken at TP-1 where a temporary stake is set. The instrument is not moved to take this reading, which is called a foresight (FS) reading. A FS reading is taken at a point of unknown elevation and is called a "minus sight" since it is subtracted from the HI to give the elevation at the new point. The elevation or HI at TP-1 is 99.34 (103.02 - 3.68). TP-1 now has a known elevation and can be used when the instrument is moved.

d. The survey should be continued until a complete circuit is made, and the last FS is taken at BM-1. This is necessary to check the accuracy of the survey.

The final reading in most cases will not be exactly the same as the 100.00 feet which was used at the start. If there is a difference between the original reading and the last reading, this indicates an error. A reasonable allowance can be made for errors. The following formula may be used to determine a reasonable, allowable error:

Allowable error = .014 times the square root of the length of the traverse in feet divided by 100.

There is also a "rule of thumb" that may be applied to determine allowable error. If the turning point readings are approximately 150 feet in length, the allowable error may be computed by multiplying .01 feet times the number of instrument settings.

Field notes must be kept when differential leveling. Sample field notes made from the readings in the preceding example are shown at right.

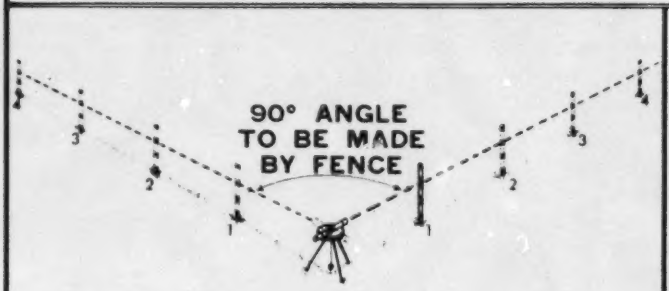
DIFFERENTIAL LEVELING FIELD NOTES

Sta.	BS	HI	FS	Elev.	Dist.
BM-1	3.02			100.00	
		103.02			250
TP-1	3.34		3.68	99.34	
		102.68			270
TP-2	4.00		4.17	98.51	
		102.51			330
TP-3	3.56		3.95	98.56	
		102.12			300
TP-4	5.00		3.12	99.00	
		104.00			320
TP-5	7.24		3.62	100.38	
		107.62			370
BM-2	3.51		0.46	107.16	
		110.67			320
TP-6	5.42		4.34	106.33	
		111.75			280
TP-7	4.87		4.81	106.94	
		111.81			310
TP-8	1.92		4.28	107.53	
		109.45			260
BM-1			9.43	100.02	
				=	3010
		Error = 0.02'			
Allowable error = .014 $\sqrt{\frac{3010}{100}}$				= 0.08'	

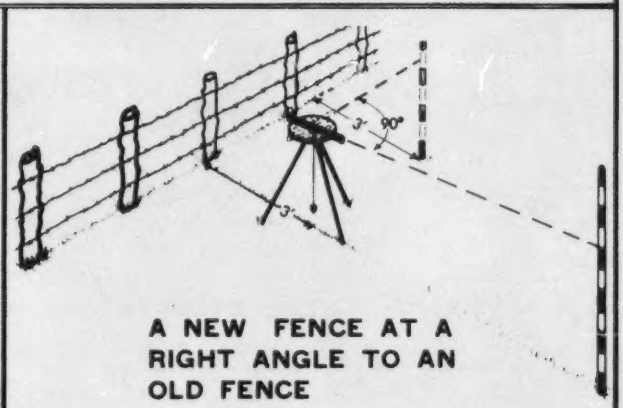
9. STAKING OUT FENCE LINES

The best instrument for staking out fences is one that can be moved vertically as well as horizontally; however, a farm level may be used. The procedure is the same for a completely new fence line or a new fence line at a right angle to an existing fence.

STAKING OUT FENCE LINES



COMPLETELY NEW FENCE



A NEW FENCE AT A RIGHT ANGLE TO AN OLD FENCE

The following four steps should be taken in staking out fence lines:

Step 1 - The instrument is set up with the plumb bob bisecting a corner stake of a completely new fence. The telescope is pointed in the direction of the fence line, and the graduate circle is placed at zero degrees. The stakes are aligned with the vertical cross-hair. After the stakes are aligned in one fence line, one would proceed with steps 2 through 4.

If a new fence is being staked out at a right angle to an old fence, a stake in the new fence line is driven three or four feet from the existing fence. Another stake should be driven about 20 feet from the first stake and the same distance from the fence as the first stake. This stake and the stake which the plumb bob bisects are parallel to the fence. The cross-hair in the telescope should bisect the second stake. Proceed with steps 2 through 4.

Step 2 - The graduate circle is set at zero.

Step 3 - The telescope is turned until the graduate circle reads 90 degrees and points in the direction of the proposed fence line.

Step 4 - Stakes are set in the new fence line. A tape is used to measure the distance, and the telescope is used to align the stakes.

After several stakes have been set, it may be necessary to move the instrument. When the instrument is moved, it should be set over the last stake so that the plumb bob bisects the stake. A backward sight is taken on a stake, and the graduate circle is set at zero degrees. The telescope is then turned 180 degrees. The instrument is now prepared for sighting the rest of the stakes, and the same procedure may also be used to align the posts after the holes are dug.

SUGGESTED STUDENT ACTIVITIES

I. True or False.

_____ 1. The two types of farm levels are the turret and the utility.

_____ 2. The level is a durable instrument and need not be protected from shock and vibration.

_____ 3. Leveling screws should be tightened with pliers.

_____ 4. Leveling the turret type level requires placing the telescope over two of the leveling screws and rotating the screws in opposite directions by moving the thumbs toward or away from each other.

_____ 5. When the bubble tube is directly over two leveling screws, the bubble should be in the center of the two corresponding vial lines.

_____ 6. The telescope should be adjusted so that the line of sight is slightly to the right of the operator.

_____ 7. If the cross-hair is out of adjustment, gently tap the telescope with the heel of the hand.

_____ 8. The rod is used to measure elevation or comparative heights of objects in their relation to the height of the instrument.

_____ 9. Allowing the rod to lean to one side will cause the reading to be inaccurate.

_____10. The base of the rod should be placed on a clod to get an accurate reading.

_____11. Foundations that are not rectangular cannot be staked out by using the level.

_____12. The strings attached to batter boards must intersect directly over the four corners of a proposed foundation.

_____13. Differential leveling requires adding the BS reading to the last known point to determine the height of instrument.

_____14. The FS reading is subtracted from the HI to determine the elevation at a designated point.

_____15. The level can be used to lay out fence lines with stakes and to align posts after the holes are dug.

II. Define the following terms:

1. Differential Leveling -

2. Starting Point -

3. Back Sight -

4. Height of Instrument -

5. Fore Sight -

6. Turning Point -

7. Double Rod Leveling -

8. Instrument Operator -

9. Rodman -

10. Tripod Level -

III. Identify the following hand signals:

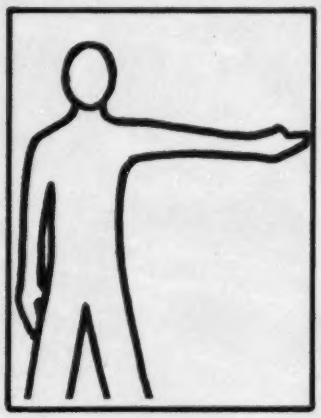
1. _____

2. _____

3. _____

4. _____

5. _____



6. _____

7. _____

8. _____

IV. Multiple Choice (underline correct answer).

1. When differential leveling, the point at which elevation is known or assumed to be 100 feet above sea level is called the:
   a. bench mark
   b. elevation mark
   c. leveling mark

2. If two rod readings were taken 100 feet apart and the readings were 4.5 feet and 1.5 feet, the percent slope would be:
   a. .3 percent
   b. 3 percent
   c. .03 percent

3. The turret type farm level has the following number of leveling screws:
   a. five
   b. four
   c. three

4. When setting up the tripod, the legs should be set firmly and at least _____ feet apart.
   a. 3 1/2
   b. 3
   c. 2 1/2

5. The farm level should be checked for accuracy:
   a. yearly
   b. each time before it is used
   c. only after it has been dropped or misused

6. The Philadelphia, architect, and self-reading target rods are graduated in:
   a. yards, feet, inches
   b. feet, inches, eighths
   c. feet, tenths, hundredths

V. Skills to be performed by the student.

1. Identify types of levels and parts of each.

2. Set up, check, and test a leveling instrument.

3. Take rod readings and use correct signals at turning points.

4. Stake out a foundation.

5. Complete a differential leveling exercise.

6. Stake out a fence line.

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